Reliability & Maintainability Predictions Report (R&MPR) for the Surface, Water and Air Biocharacterization (SWAB) Air Sampling Device (ASD)

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Reliability & Maintainability Predictions Report (R&MPR)
for the
Surface, Water and Air Biocharacterization (SWAB)
Air Sampling Device (ASD)

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TBD

1 INTRODUCTION

This report contains the Reliability & Maintainability Prediction Report (R&MPR) for the International Space Station (ISS) Surface, Water and Air Biocharacterization (SWAB) Air Sampling Device (ASD).

1.1 Purpose

The purpose of this R&MPR is to estimate reliability and maintenance aspects of the ASD and to make recommendations based on the results of the prediction.

1.2 Scope

This report predicts reliability, availability, and maintainability characteristics for the ASD. This estimate is intended as an input to management to be used in combination with other types of design and operational data to aid in upcoming project decisions. The R&MPR involves the development of system Reliability Block Diagrams (RBD) and failure prediction methodologies, which are discussed in section 3.

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable Documents

The following documents, of the exact date and revision shown, form a part of this document to the extent specified herein.

Document Number	Revision/ Release Date	Document Title
TBD	TBD	TBD

2.2 Reference Documents

The following documents are reference documents utilized in the development of this document. These documents do not form a part of this document, and are not controlled by their reference herein.

Document Number	Revision/ Release Date	Document Title
LS-20444-1	BASIC/ 09/2003	System Requirements Document for the Human Research Facility (HRF) Surface, Water, and Air Biocharacterization (SWAB) Experiment System

2.3 Order of Precedence

In the event of a conflict between the requirements specified in this document and an applicable document cited herein, the text of this document takes precedence.

3 METHODOLOGY

Reliability predictions for the ASD follow a specific methodology. The ASD RBD is constructed and propagated with component reliability data. The reliability and availability of the ASD is then predicted.

3.1 Rapid Availability Prototyping for Testing Operational Readiness (RAPTOR)

Reliability models for the ASD are created by using RAPTOR 6.0. RAPTOR utilizes an RBD structure to represent a system's components graphically. Blocks represent individual components and are tied together with lines and nodes to define the overall logic of the system. RAPTOR handles series, parallel, complex, cold standby, and phased RBDs, models failure and repair parameters, and allows 16 different failure distributions for any component.

3.2 Vendor Data

The first option for component reliability data is the vendor. In many cases vendors do not perform reliability testing on their products; therefore, mean time between failure (MTBF) or mean cycles between failure (MCBF) data are not available. Many vendors do warranty components for a specified time. From a reliability perspective, a warranty period is not particularly useful. But if an assumption is made that a warranty period has an associated failure rate, the MTBF can be calculated based on a given failure distribution. For the purposes of this analysis, a vendor guarantee is assumed to represent a 95th percentile component population.

3.3 PRISM

PRISM 1.5 is used to estimate the reliability of components where no vendor data is available. PRISM is a software tool that performs failure rate assessments based on a methodology developed by the Reliability Analysis Center (RAC) for the U.S. Air Force. It contains an extensive database of failure rates based on Electronic Parts Reliability Data (EPRD)-97 and Nonelectronic Parts Reliability Data (NPRD)-95. As the BTF design matures, PRISM (or a similar program) will supplant RAPTOR as the system-level reliability predictor. The final reliability prediction will be refined to reflect global parameters such as environmental stresses.

3.4 Maintainability

This document contains maintenance information on the ASD. Limited life items, shelf life items, and planned maintenance are also covered.

4 ASD SYSTEM DESCRIPTION

4.1 Hardware Description

The ASD is a modified COTS environmental Air Sampling System manufactured by Sartorius Co. The ASD operates by drawing air across the ASD Filter via an integrated impeller/motor system. An opto-electronic anemometer measures the flow rate of the air passing through the inlet port of the ASD and is used to control the impeller/motor system.

The flow rate is selected by the user. If the flow rate is reduced or accelerated by obstruction or holes in the filter, the system compensates for the change and will reduce or increase the current to the impeller/motor system. With a precisely controlled flow rate, the volume of air acquired and time required will allow precise measurements of the air samples. The amount of air and sample rate that the ASD will be operated at is 1m^3 (1000 L) at 50 L/min for a total operational time of 20 minutes.

To power the SWAB ASD for extended increments, a unique battery pack was designed utilizing five (5) Li-BCX "C" sized cells constructed in a series configuration. Each cell is a 3.4V battery cell procured from USA's Class I battery inventory. The Battery pack is configured with advanced safety features including reverse current protection diodes (2 per cell) as well as a polyswitch to prevent over discharge and excessive heat generation. The battery pack has been tested to operate up to about 10 hours of use, which will provide enough time to acquire the proposed 8 hours of use per increment. An extra battery pack will be flown for contingency use. One device will be flown per increment.

The ASD unit life is one year from the time of from the time of final certification.

4.2 ASD Reliability Block Diagram

The RBD for the ASD can be seen in Figure 4-1:

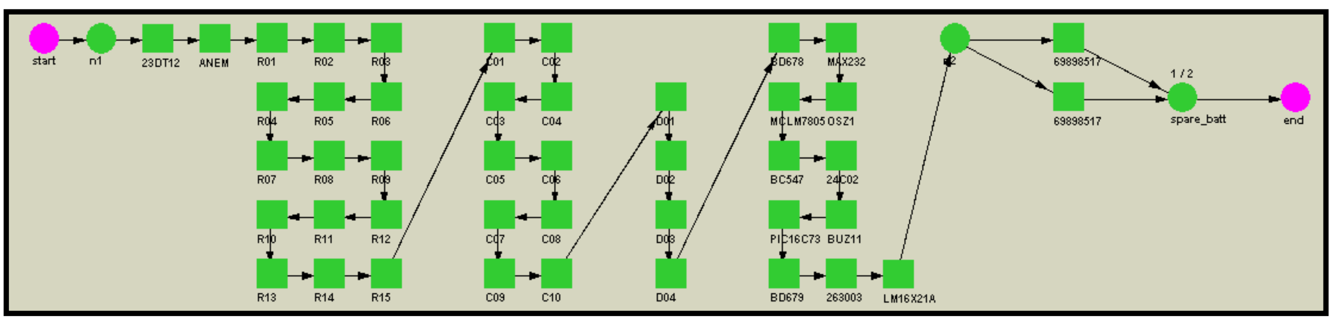


Figure 4-1: ASD Reliability Block Diagram

The figure demonstrates that the ASD has no electrical component redundancies. All blocks in series are single point failures; thus, a failure of any electrical component of the ASD is considered a failure of the ASD. The parallel portion of the reliability block diagram represents the ASD battery pack which is spared on-orbit. For the purposes of determining the overall reliability of the ASD, the “spare_batt” node is set to cold standby.

5 ASD RELIABILITY AND MAINTAINABILITY

5.1 ASD Input Data

Table 5-1 shows the reliability data used for ASD components.

Block Name	Component	λ (Failures / 1E6 Hours)
23DT12	DC Motor	8.9879E-1
ANEM	Anemometer	5.4651E-2
RXX	Resistor	3.6654E-2*
CXX	Capacitor	1.2063E-2*
DXX	Diode	4.8140E-3*
BD678	Plastic Medium-Power Silicon PNP Darlington	2.8690E-3†
MC/LM7805	3-Terminal 1A Positive Voltage Regulator	5.6410E-3
BC547	NPN General Purpose Transistor	1.4944E-2
PIC16C73	8-Bit CMOS Microcontroller with A/D Converter	5.6410E-3
BD679	Plastic Medium-Power Silicon PNP Darlington	2.8690E-3†
MAX232	5V Multichannel RS-232 Driver/Receiver	1.9000E-3
OSZ1	10MHz Oscillator / Clock	8.9796E-2
24C02	EEPROM	4.1470E-3
BUZ11	MOSFET	1.6971E-2
263003	PICO® II 250 Volt Very Fast-Acting Fuse	2.3991E-2
LM16X21A	16 characters x 2 lines Backlit LCD display	6.5069E-2
69898517	Battery Pack	9.9538E-2
* The stated reliability represents the entire family of components † Vendor-supplied data		

Table 5-1. ASD Input Summary Data

5.2 ASD Reliability Simulation Assumptions

The model shown in Figure 4-1 was propagated with process-graded PRISM data from Table 5-1 and run with the following assumptions:

- Simulation time = 1 year
- Simulation conducted for 10,000 iterations
- PRISM merged and process-graded failure rates are sufficient analogues for ASD components
- R = 1 for components not represented in RBD
- Exponential distribution for failure rate
- ASD operated within nominal ISS cabin environmental envelope
- An ASD battery failure is recoverable with single cold-standby on-orbit spare
- The ASD is continuously operated on-orbit (100% duty cycle far exceeds actual on-orbit operational rate, which provides a conservative reliability prediction)

The ASD model does not provide a replacement ASD in the event of a failure. Ground-based sparing is carried on the BTF-level model.

5.3 ASD Reliability Prediction

The ASD reliability model was propagated with component reliability data and the simulation was conducted for one year. This is clearly a worst-case scenario from a reliability perspective; in actuality the ASD has a duty cycle of less than 1%. The results from the RAPTOR run are:

$$R_{ASD} = 0.990$$

$$A_{iASD} = 0.995$$

The predicted reliability reflects the robust and simple design of the SWAB ASD. The low parts count and commercial-grade quality of the components make the ASD a highly reliable device. Additionally, the low duty cycle of the ASD increases the overall predicted reliability above the already high threshold.

5.4 ASD Maintainability

The ASD requires no on-orbit maintenance. Functional tests and pre-delivery inspections are performed on the ground prior to delivery for flight.

6 CONCLUSIONS AND RECOMMENDATIONS

The Surface, Water and Air Biocharacterization (SWAB) Air Sampling Device (ASD) was analyzed to determine its theoretical reliability characteristics. An RBD was created in RAPTOR and propagated with component data from vendors and PRISM's user database. The calculated reliability was .990 for one year of continuous operation.

The low duty cycle for the ASD's actual on-orbit operation will allow verification of reliability prediction by ground-based Accelerated Life Testing (ALT) prior to initial flight. The data gathered from ground-based testing will allow the initial reliability predictions to be refined via Bayesian analysis.

It is important to note that reliability modeling is not a replacement for Accelerated Life Testing (ALT), Highly Accelerated Life Testing (HALT), or "shake and bake" testing. The models presented in this document represent a component-level look at the ASD. As such, the data should be interpreted as a basis for determining sparing strategies and understanding (from a comparative standpoint) the theoretical reliability characteristics of the ASD. The synergistic effects of design and component selection can only be determined by real-world testing. ALT drives out the types of design flaws that are not captured by traditional methods of reliability prediction, and the combination of reliability prediction and ALT increases the overall understanding of the ASD's operational reliability characteristics.

APPENDIX A ACRONYMS AND ABBREVIATIONS

TBD	TBD

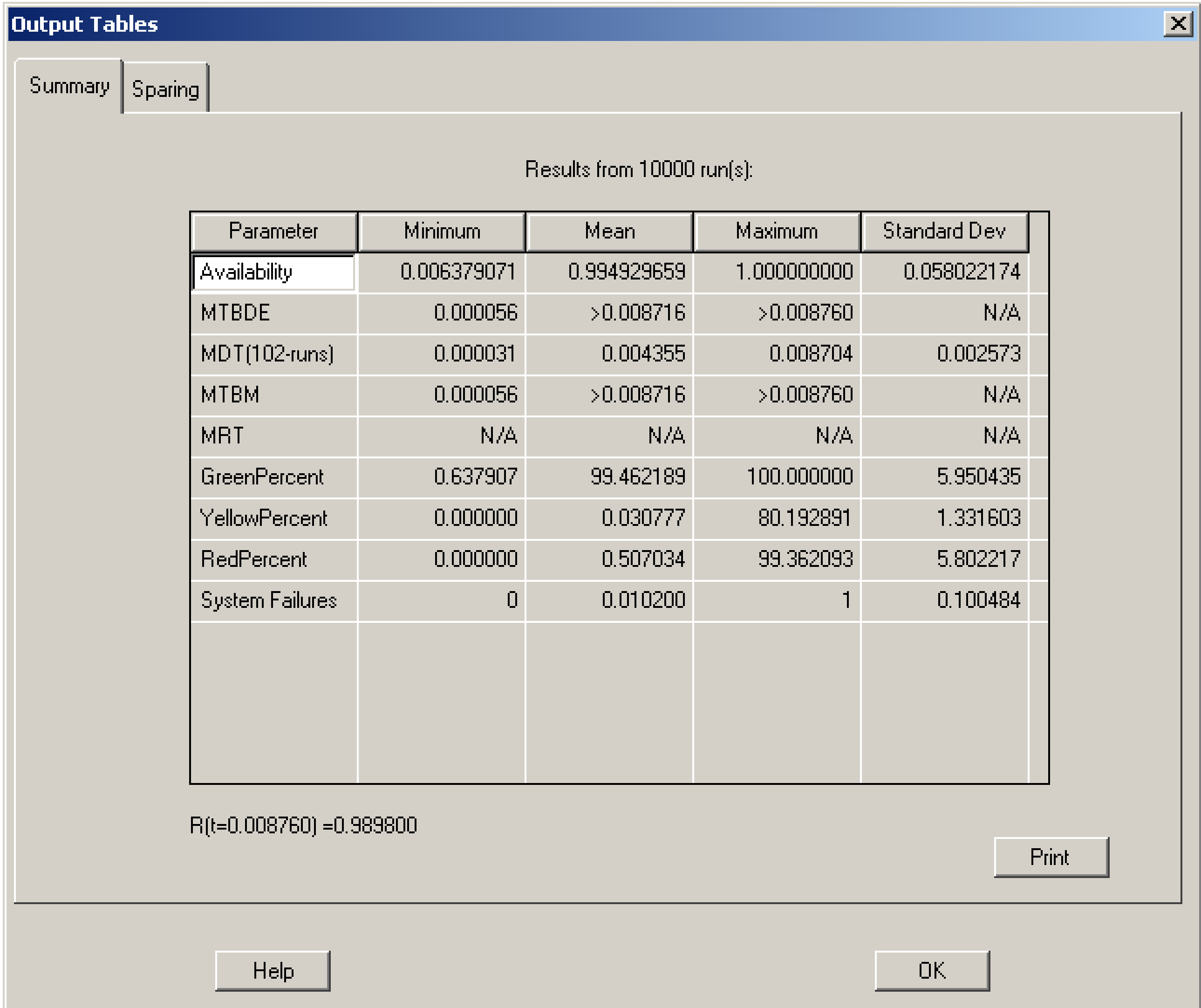
APPENDIX B   RAW DATA

ASD PRISM DATA

Part Category	Part Type	Qty	ID	Part Description	PGF	λ (Assy)	Assy Qty	λ (RACdat)	λ (usrdef)
System		**1**	**ASD**	**SWAB**	**0.788738012**	**N/A**	**1**	**N/A**	**N/A**
ASSEMBLY		**1**		**Compressor Unit**	**0.788738121**	**0.953443781**	**1**	**0.953443781**	**N/A**
OTHER	MOTOR, ELECTRICAL, DC	1	ESCAP 23DT12	OTHER, MOTOR, ELECTRICAL, DC	N/A	N/A	N/A	0.898792982	N/A
OTHER	TRANSDUCER, AIR FLOW, VELOCITY	1		OTHER, TRANSDUCER, AIR FLOW, VELOCITY	N/A	N/A	N/A	0.054650798	N/A
ASSEMBLY		**1**		**Battery Pack, LiBCX**	**0.788738118**	**0.099537997**	**1**	**0.099537997**	**N/A**
OTHER	BATTERY, LITHIUM, BROMINE CHLORIDE	5		OTHER, BATTERY, LITHIUM, BROMINE CHLORIDE	N/A	N/A	N/A	0.019907599	N/A
ASSEMBLY		**1**		**Boards (charging and control)**	**0.788738121**	**0.233837838**	**1**	**0.178855797**	**0.005738**
IC	LINEAR, VOLTAGE REGULATOR, FIXED, POSITIVE	1	MC/LM 7805	IC, LINEAR, VOLTAGE REGULATOR, FIXED, POSITIVE	N/A	N/A	N/A	N/A	N/A
TRANSISTOR	BIPOLAR, MULTIPLE, DARLINGTON, PNP	1	BD678	TRANSISTOR, BIPOLAR, MULTIPLE, DARLINGTON, PNP	N/A	N/A	N/A	N/A	0.002869
TRANSISTOR	BIPOLAR, NPN	1	BC547	TRANSISTOR, BIPOLAR, NPN	N/A	N/A	N/A	N/A	N/A
IC	LINEAR, CONVERTER, A/D, 8 BIT	1	PIC16C73	IC, LINEAR, CONVERTER, A/D, 8 BIT	N/A	N/A	N/A	N/A	N/A
TRANSISTOR	BIPOLAR, DARLINGTON, POWER, NPN	1	BD679	TRANSISTOR, BIPOLAR, DARLINGTON, POWER, NPN	N/A	N/A	N/A	N/A	0.002869
IC	DIGITAL, DRIVER, RECEIVER	1	MAX232	IC, DIGITAL, DRIVER, RECEIVER	N/A	N/A	N/A	N/A	N/A
OTHER	OSCILLATOR, CLOCK	1	OSZ1	OTHER, OSCILLATOR, CLOCK	N/A	N/A	N/A	0.089795597	N/A
IC	DIGITAL, MEMORY, EEPROM	1	24C02	IC, DIGITAL, MEMORY, EEPROM	N/A	N/A	N/A	N/A	N/A
TRANSISTOR	FIELD EFFECT, MOS, N-CHANNEL	1	BUZ11	TRANSISTOR, FIELD EFFECT, MOS, N-CHANNEL	N/A	N/A	N/A	N/A	N/A
OTHER	FUSE, TERMINAL LINK	1	263003	OTHER, FUSE, TERMINAL LINK	N/A	N/A	N/A	0.023991	N/A
OTHER	DISPLAY, LED, NUMERIC, DOT TYPE	1	LM16X21A	OTHER, DISPLAY, LED, NUMERIC, DOT TYPE	N/A	N/A	N/A	0.0650692	N/A
ASSEMBLY		**1**		**Capacitors**	**0.788738121**	**0.012063279**	**1**	**N/A**	**N/A**
CAPACITOR	FIXED	10		CAPACITOR, FIXED	N/A	N/A	N/A	N/A	N/A
ASSEMBLY		**1**		**Resistors**	**0.788738118**	**0.03665395**	**1**	**N/A**	**N/A**

RESISTOR	FIXED	15		RESISTOR, FIXED	N/A	N/A	N/A	N/A	N/A
ASSEMBLY		**1**		**Diodes**	**0.788738121**	**0.004813904**	**1**	**N/A**	**N/A**
DIODE	SMALL SIGNAL	2	1N4148	DIODE, SMALL SIGNAL	N/A	N/A	N/A	N/A	N/A
DIODE	GENERAL PURPOSE	1	FE2D	DIODE, GENERAL PURPOSE	N/A	N/A	N/A	N/A	N/A
DIODE	RECTIFIER	1	1N4007	DIODE, RECTIFIER	N/A	N/A	N/A	N/A	N/A

ASD RAPTOR OUTPUT DATA



Results from 10000 run(s):

Parameter	Minimum	Mean	Maximum	Standard Dev
Availability	0.006379071	0.994929659	1.000000000	0.058022174
MTBDE	0.000056	>0.008716	>0.008760	N/A
MDT(102-runs)	0.000031	0.004355	0.008704	0.002573
MTBM	0.000056	>0.008716	>0.008760	N/A
MRT	N/A	N/A	N/A	N/A
GreenPercent	0.637907	99.462189	100.000000	5.950435
YellowPercent	0.000000	0.030777	80.192891	1.331603
RedPercent	0.000000	0.507034	99.362093	5.802217
System Failures	0	0.010200	1	0.100484

R(t=0.008760) =0.989800